Ch 11 Molecular Composition of Gases

Ch 11 Molecular Composition of Gases

Gay-Lussac - working w/ Reacting Gases

Ch 11 Molecular Composition of Gases

Gay-Lussac - working w/ Reacting Gases

H(g) + Cl(g) → HCl(g)

1vol 1vol 2vol

Ch 11 Molecular Composition of Gases

Gay-Lussac - working w/ Reacting Gases

$H_{(g)} + Cl_{(g)} \rightarrow HCl_{(g)}$

1vol 1vol 2vol

$2H_{(g)} + O_{(g)} \rightarrow H_2O_{(g)}$

2vol 1vol 2vol

Ch 11 Molecular Composition of Gases

Gay-Lussac's Law of Combining Volumes → @ const T + P the vol of React/Prod gases can be expressed in small whole # Ratios

H(g) + Cl(g) → HCl(g)

1 vol   1 vol   2 vol

2H(g) + O(g) → H_2O(g)

2 vol   1 vol   2 vol

Ch 11 Molecular Composition of Gases

Gay-Lussac's Law of Combining Volumes — @ const T + P the vol of React/Prod gases can be expressed in small whole # Ratios

Avogadro's Principle

@ const T + P equal volumes of gases will have equal #'s of particles

$H_{(g)}$	+	$Cl_{(g)}$	→	$HCl_{(g)}$
1vol		1vol		2vol
$2H_{(g)}$	+	$O_{(g)}$	→	$H_2O_{(g)}$
2vol		1vol		2vol

Ch 11 Molecular Composition of Gases

Gay-Lussac's Law of Combining Volumes — @ const T + P the vol of React/Prod gases can be expressed in small whole # Ratios

Avogadro's Principle

@ const T + P equal volumes of gases will have equal #'s of particles

$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

1 vol, 1 vol, 2 vol

$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

2 vol, 1 vol, 2 vol

Ch 11 Molecular Composition of Gases

Gay-Lussac's Law of Combining Volumes } @ const T + P the vol of React/Prod gases can be expressed in small whole # Ratios

Avogadro's Principle

@ const T + P equal volumes of gases will have equal #'s of particles

$H_{2(g)}$ + $Cl_{2(g)}$ → $2HCl_{(g)}$

1vol 1vol 2vol

$2H_{2(g)}$ + $O_{2(g)}$ → $2H_2O_{(g)}$

2vol 1vol 2vol

Avogadro suggests some elements are diatomic to Resolve conflict

Molar Volume of a Gas

Molar Volume of a Gas

↳ Based on Avogadro's Principle (Equal vol of gases have equal # of particles)
there must a volume that
one mole of any gas will occupy @ STP

↳ $\frac{22.4L}{1mol}$ Molar Vol

What vol will 12.0 g
of Cl_2 occupy @ STP?

How many mol of Ar
are in 2800 mL @ STP?

What vol will 12.0 g of Cl_2 occupy @ STP?

$12.0\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{71.0\,g\,Cl_2}$

How many mol of Ar are in 2800 mL @ STP?

What vol will 12.0 g of Cl_2 occupy @ STP?

$$12.0\,g\ Cl_2 \times \frac{1\,mol\ Cl_2}{71.0\,g\ Cl_2} \times \frac{22.4\,L\ Cl_2}{1\,mol\ Cl_2} = 3.78\ L\ Cl_2$$

How many mol of Ar are in 2800 mL @ STP?

What vol will 12.0 g of Cl_2 occupy @ STP?

$12.0\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{71.0\,g\,Cl_2} \times \frac{22.4\,L\,Cl_2}{1\,mol\,Cl_2} = 3.78\,L\,Cl_2$

How many mol of Ar are in 2800 mL @ STP?

$2800\,mL\,Ar \times \frac{1\,L}{1000\,mL} \times$

What vol will 12.0 g of Cl_2 occupy @ STP?

$$12.0\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{71.0\,g\,Cl_2} \times \frac{22.4\,L\,Cl_2}{1\,mol\,Cl_2} = 3.78\,L\,Cl_2$$

How many mol of Ar are in 2800 mL @ STP?

$$2800\,mL\,Ar \times \frac{1\,L}{1000\,mL} \times \frac{1\,mol\,Ar}{22.4\,L\,Ar} = 1.3\,mol\,Ar$$

Gas Density -

$D = \frac{m}{V}$

Gas Density -

↳ If gas known, you know Molar Mass $\left(\frac{g}{mol}\right)$ & Molar vol $\left(\frac{mol}{L}\right)$

$D = \frac{m}{V}$

Gas Density -

↳ If gas known, you know Molar Mass $\left(\frac{g}{mol}\right)$ & Molar vol $\left(\frac{L}{mol}\right)$

$D = \frac{m}{V}$

$D_{STP} = \frac{\text{molar mass}}{\text{molar vol}}$

Gas Density -

↳ If gas known, you know Molar Mass (g/mol) & Molar Vol (L/mol)

$D = \frac{m}{V}$

$D_{STP} = \frac{\text{Molar Mass}}{\text{Molar Vol}}$

D_{Ar} @ STP = ?

Gas Density -

↳ If gas known, you know Molar Mass ($\frac{g}{mol}$) & Molar vol ($\frac{L}{mol}$)

$D = \frac{m}{V}$

$D_{STP} = \frac{\text{molar mass}}{\text{molar vol}}$

D_{Ar} @ STP = ?

$D_{Ar} = \frac{39.9 \frac{g}{mol}}{22.4 \frac{L}{mol}} = 1.79 \frac{g}{L}$

Ideal Gas Law

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Charles's Law $V \propto T$

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Charles's Law $V \propto T$

Avogadro's Law $V \propto n$

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Charles's Law $V \propto T$

Avogadro's Law $V \propto n$

$V \propto n \times T \times \frac{1}{P}$

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Charles's Law $V \propto T$

Avogadro's Law $V \propto n$

$V \propto n \times T \times \frac{1}{P}$

$V = \frac{nT}{P} \times R$ ← Ideal Gas constant

Ideal Gas Law

Boyle's Law $V \propto \frac{1}{P}$

Charles's Law $V \propto T$

Avogadro's Law $V \propto n$

$$V \propto n \times T \times \frac{1}{P}$$

$$V = \frac{nT}{P} \times R$$ ← Ideal Gas constant

$PV = nRT$ Ideal Gas Law

$PV = nRT$

$R = \frac{PV}{nT}$

$$R = \frac{PV}{nT} = \frac{(1\,atm)(22.4\,L)}{(1\,mol)(273\,K)}$$

$$R = \frac{PV}{nT} = \frac{(1\,atm)(22.4\,L)}{(1\,mol)(273\,K)} = 0.0821\,\frac{L\,atm}{mol\,K}$$

What volume will 30.3g
of Chlorine occupy @ 800.3 torr
and -32.0 C ?

What volume will 30.3g of Chlorine occupy @ 800.3 torr and -32.0 C?

P

V

n

T

What volume will 30.3g of Chlorine occupy @ 800.3 torr and -32.0 C?

P = 800.3 torr
V = ?
n
T = -32.0 C

What volume will 30.3 g of chlorine occupy @ 800.3 torr and -32.0 C?

P = 800.3 torr

V = ?

$n = 30.3\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{71.0\ g\ Cl_2} = 0.426\ mol\ Cl_2$

T = -32.0 C

What volume will 30.3g of Chlorine occupy @ 800.3 torr and -32.0 C?

P = 800.3 torr

V = ?

$n = 30.3\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{71.0\,g\,Cl_2} = 0.426\,mol\,Cl_2$

$T = -32.0\,C + 273 = 241\,K$

What volume will 30.3 g of chlorine occupy @ 800.3 torr and -32.0 C?

$P = 800.3\ torr \times \frac{1\ atm}{760\ torr} = 1.05\ atm$

$V = ?$

$n = 30.3\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{71.0\ g\ Cl_2} = 0.426\ mol\ Cl_2$

$T = -32.0\ C + 273 = 241\ K$

What volume will 30.3 g of Chlorine occupy @ 800.3 torr and -32.0 C ?

$P = 800.3\text{ torr} \times \frac{1\text{ atm}}{760\text{ torr}} = 1.05\text{ atm}$

$V = ?$

$n = 30.3\text{ g } Cl_2 \times \frac{1\text{ mol } Cl_2}{71.0\text{ g } Cl_2} = 0.426\text{ mol } Cl_2$

$T = -32.0\,C + 273 = 241\text{ K}$

$V = \frac{nRT}{P}$

$= \frac{(0.426\text{ mol})(0.0821\frac{L\,atm}{mol\,K})(241\text{ K})}{1.05\text{ atm}}$

$= 8.04\text{ L}$

Derivations of Ideal Gas Law

Derivations of Ideal Gas Law

$PV = nRT$

Derivations of Ideal Gas Law

$$PV = nRT$$

$$n = \frac{m}{\mathcal{M}}$$

Derivations of Ideal Gas Law

$$PV = nRT$$

$$n = \frac{m}{\mathcal{M}}$$

m: mass

Derivations of Ideal Gas Law

$$PV = nRT$$

$$n = \frac{m}{\mathcal{M}}$$

m = mass

$\mathcal{M}$ = Molar Mass

Derivations of Ideal Gas Law

$$PV = nRT \quad \text{and} \quad n = \frac{m}{\mathcal{M}} \;\longrightarrow\; PV = \frac{mRT}{\mathcal{M}}$$

m = mass

$\mathcal{M}$ = Molar Mass

Derivations of Ideal Gas Law

$$PV = nRT, \quad n = \frac{m}{\mathcal{M}} \longrightarrow PV = \frac{mRT}{\mathcal{M}} \therefore \mathcal{M} = \frac{mRT}{PV}$$

m: mass

$\mathcal{M}$: Molar Mass

Derivations of Ideal Gas Law

$$PV = nRT$$

$$n = \frac{m}{\mathcal{M}}$$

$$\rightarrow PV = \frac{mRT}{\mathcal{M}} \therefore \boxed{\mathcal{M} = \frac{mRT}{PV}}$$

m = mass

$\mathcal{M}$ = Molar Mass

Derivations of Ideal Gas Law

$PV = nRT$

$n = \frac{m}{\mathcal{M}}$

$\rightarrow PV = \frac{mRT}{\mathcal{M}} \therefore \boxed{\mathcal{M} = \frac{mRT}{PV}}$

$D = \frac{m}{V}$

m: mass

$\mathcal{M}$: Molar Mass

Derivations of Ideal Gas Law

$$PV = nRT$$

$$n = \frac{m}{\mathcal{M}}$$

$$\rightarrow PV = \frac{mRT}{\mathcal{M}} \;:\; \boxed{\mathcal{M} = \frac{mRT}{PV}}$$

m: mass

$\mathcal{M}$: Molar Mass

$$D = \frac{m}{V}$$

$$\mathcal{M} = \frac{DRT}{P}$$

Derivations of Ideal Gas Law

$$PV = nRT, \quad n = \frac{m}{\mathcal{M}} \rightarrow PV = \frac{mRT}{\mathcal{M}} \therefore \boxed{\mathcal{M} = \frac{mRT}{PV}}$$

m: mass

$\mathcal{M}$: Molar Mass

$$D = \frac{m}{V}$$

$$\mathcal{M} = \frac{DRT}{P} \Rightarrow \boxed{D = \frac{\mathcal{M}P}{RT}}$$

m = 1.25

V = 350. mL

T = 20.0 °C

P = 750. mmHg

$\mathcal{M}$ = ?

$$\mathcal{M} = \frac{mRT}{PV}$$

$m = 1.25\ g$

$V = 350.\ mL \times \frac{1\ L}{1000\ mL} = 0.350\ L$

$T = 20.0\ °C$

$P = 750.\ mmHg$

$\mathcal{M} = ?$

$\mathcal{M} = \frac{mRT}{PV}$

m = 1.25 g

$V = 350.\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} = 0.350\text{ L}$

$T = 20.0^\circ C + 273 = 293\text{ K}$

P = 750. mmHg

$\mathcal{M} = ?$

$\mathcal{M} = \frac{mRT}{PV}$

$m = 1.25\ g$

$V = 350.\ mL \times \frac{1\ L}{1000\ mL} = 0.350\ L$

$T = 20.0^\circ C + 273 = 293\ K$

$P = 750.\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.987\ atm$

$\mathcal{M} = ?$

$\mathcal{M} = \frac{mRT}{PV}$

$m = 1.25\ g$

$V = 350.\ mL \times \frac{1\ L}{1000\ mL} = 0.350\ L$

$T = 20.0^{\circ}C + 273 = 293\ K$

$P = 750.\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.987\ atm$

$\mathcal{M} = ?$

$$\mathcal{M} = \frac{mRT}{PV}$$

$$= \frac{(1.25\ g)(0.0821\ \frac{L\ atm}{mol\ K})(293\ K)}{(0.987\ atm)(0.350\ L)}$$

$m = 1.25\ g$

$V = 350.\ mL \times \frac{1\ L}{1000\ mL} = 0.350\ L$

$T = 20.0^\circ C + 273 = 293\ K$

$P = 750.\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.987\ atm$

$\mathcal{M} = ?$

$$\mathcal{M} = \frac{mRT}{PV}$$

$$= \frac{(1.25\ g)(0.0821\ \frac{L\ atm}{mol\ K})(293\ K)}{(0.987\ atm)(0.350\ L)}$$

$m = 1.25\ g$

$V = 350.\ mL \times \frac{1\ L}{1000\ mL} = 0.350\ L$

$T = 20.0^\circ C + 273 = 293\ K$

$P = 750.\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.987\ atm$

$\mathcal{M} = ?$

$$\mathcal{M} = \frac{mRT}{PV}$$

$$= \frac{(1.25\ g)(0.0821\ \frac{L\ atm}{mol\ K})(293\ K)}{(0.987\ atm)(0.350\ L)}$$

$$= 87.4\ \frac{g}{mol}$$

If 12.8 g of sodium
React w/ an excess
of HCl, what V of
H_2 will be produced
@ STP?

If 12.8 g of sodium react w/ an excess of HCl, what V of H_2 will be produced @ STP?

$2Na + 2HCl \longrightarrow H_2 + 2NaCl$

If 12.8 g of sodium React w/ an excess of HCl, what Vol H_2 will be produced @ STP?

$2Na + 2HCl \longrightarrow H_2 + 2NaCl$

$12.8 g Na \times \frac{1 mol Na}{23.0 g Na}$

If 12.8 g of sodium React w/ an excess of HCl, what Vol H_2 will be produced @ STP?

$$2Na + 2HCl \longrightarrow H_2 + 2NaCl$$

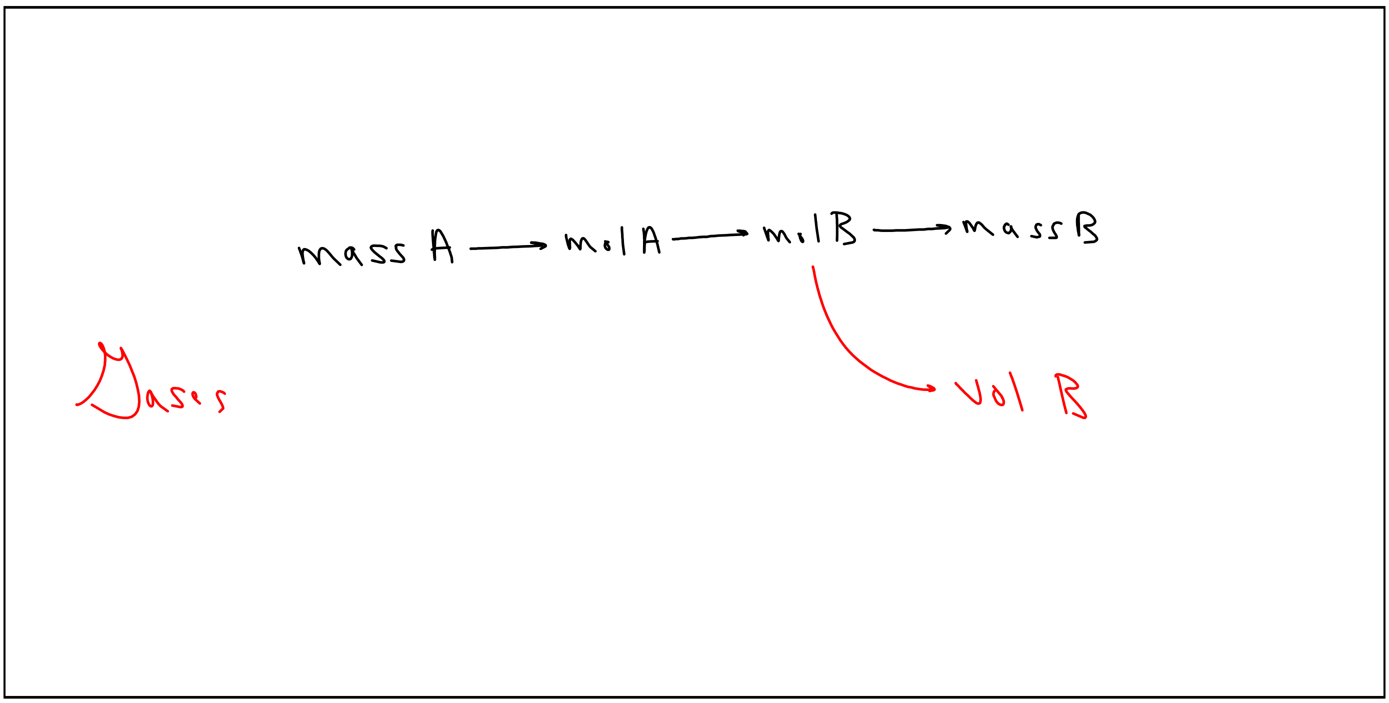
$$12.8\,g\,Na \times \frac{1\,mol\,Na}{23.0\,g\,Na} \times \frac{1\,mol\,H_2}{2\,mol\,Na}$$

If 12.8 g of sodium react w/ an excess of HCl, what Vol H_2 will be produced @ STP?

$$2Na + 2HCl \longrightarrow H_2 + 2NaCl$$

$$12.8\,g\,Na \times \frac{1\,mol\,Na}{23.0\,g\,Na} \times \frac{1\,mol\,H_2}{2\,mol\,Na} \times \frac{22.4\,L\,H_2}{1\,mol\,H_2} = 6.23\,L\,H_2$$

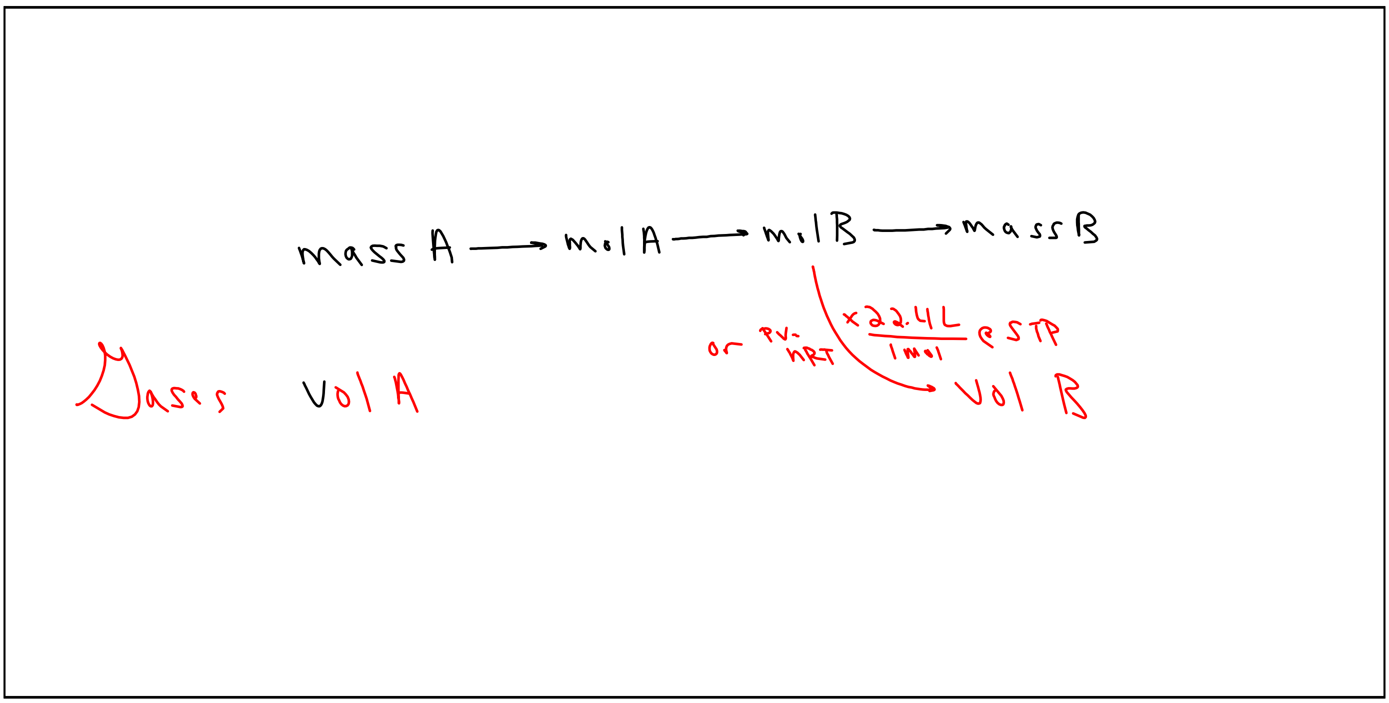
mass A ⟶ mol A ⟶ mol B ⟶ mass B

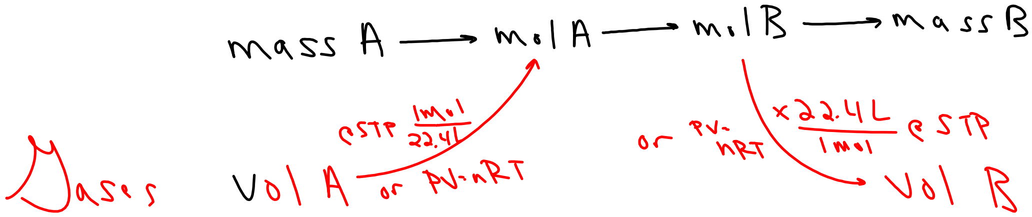

mass A → mol A → mol B → mass B
Gases
Vol B

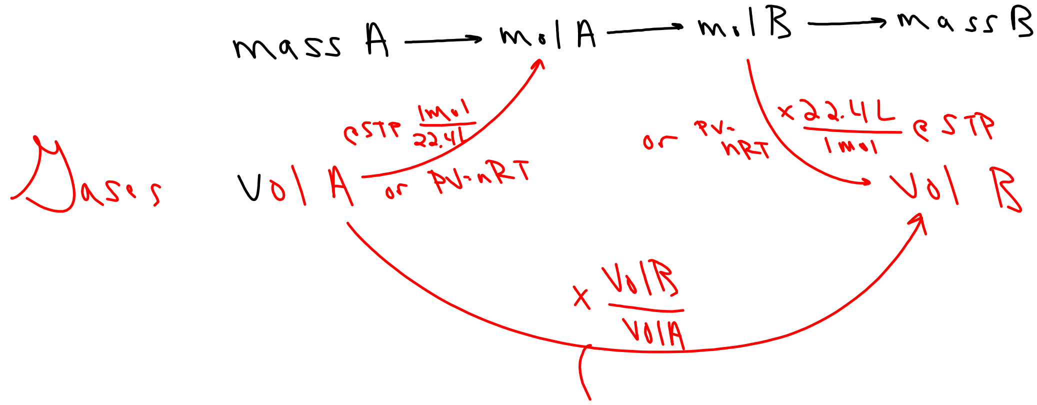
mass A → mol A → mol B → mass B

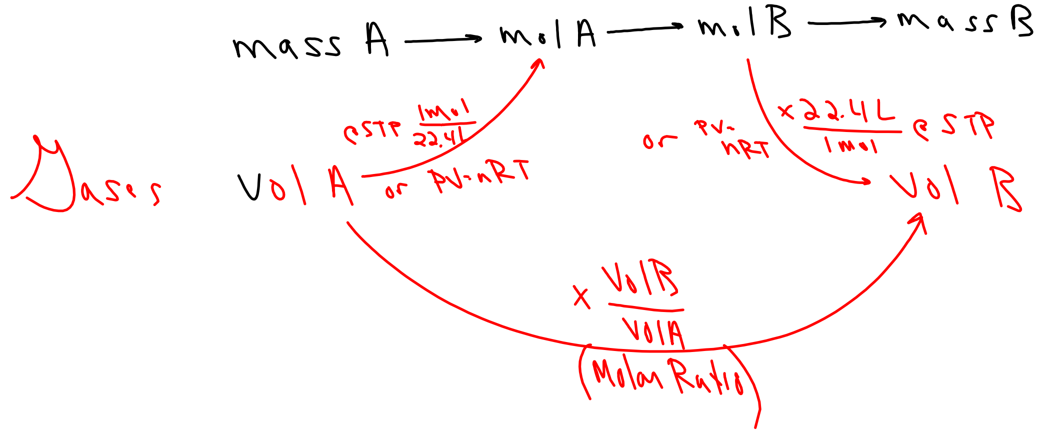
Gases

mol B → Vol B: $\times \frac{22.4\,L}{1\,mol}$ @ STP or $PV = nRT$


mass A → mol A → mol B → mass B
Gases
Vol A
or PV=nRT
x 22.4L / 1mol @ STP
Vol B


mass A → mol A → mol B → mass B
Gases
Vol A
@STP 1mol / 22.4L
or PV=nRT
or PV=nRT
x 22.4L / 1mol @STP
Vol B


mass A → mol A → mol B → mass B
Gases
Vol A
@STP 1mol / 22.4L
or PV=nRT
or PV=nRT
x 22.4L / 1mol @STP
Vol B
x Vol B / Vol A


mass A → mol A → mol B → mass B
Gases
Vol A
@STP 1mol/22.4L
or PV=nRT
x 22.4L/1mol @STP
or PV=nRT
Vol B
x Vol B/Vol A
(Molar Ratio)

vol- vol stoich

vol - vol stoich

If 12.0 L of H_2 React
w/ an excess of O_2 what
V of H_2O vapor is produced?

$2H_2 + O_2 \rightarrow 2H_2O$

vol- vol stoich

If 12.0 L of H_2 React w/ an excess of O_2 what V of H_2O vapor is produced?

12.0 L H_2

vol - vol stoich

If 12.0 L of H_2 React w/ an excess of O_2 what V of H_2O vapor is produced?

$2H_2 + O_2 \rightarrow 2H_2O$

$12.0\,L\,H_2 \times \frac{2\,L\,H_2O}{2\,L\,H_2} = 12.0\,L\,H_2O$

$2H_2 + O_2 \rightarrow 2H_2O$

vol - vol stoich

If 12.0 L of H_2 React w/ an excess of O_2 what V of H_2O vapor is produced?

@ STP

$12.0 L\ H_2 \times \frac{2 L\ H_2O}{2 L\ H_2} = 12.0 L\ H_2O$

$2H_2 + O_2 \rightarrow 2H_2O$

vol - vol stoich

If 12.0 L of H_2 React w/ an excess of O_2 what V of H_2O vapor is produced? @ STP

$12.0\,L\,H_2 \times \frac{2\,L\,H_2O}{2\,L\,H_2} = 12.0\,L\,H_2O$

$12.0\,L\,H_2 \times \frac{1\,mol\,H_2}{22.4\,L\,H_2} \times \frac{2\,mol\,H_2O}{2\,mol\,H_2} \times \frac{22.4\,L\,H_2O}{1\,mol\,H_2O} =$

$2H_2 + O_2 \rightarrow 2H_2O$

vol- vol stoich

If 12.0 L of H_2 React w/ an excess of O_2 what V of H_2O vapor is produced?

@ STP

$12.0\,L\,H_2 \times \frac{2\,L\,H_2O}{2\,L\,H_2} = 12.0\,L\,H_2O$

$12.0\,L\,H_2 \times \frac{1\,mol\,H_2}{22.4\,L\,H_2} \times \frac{2\,mol\,H_2O}{2\,mol\,H_2} \times \frac{22.4\,L\,H_2O}{1\,mol\,H_2O} =$

when 24.6g of sodium
carbonate Reacts w/
5.63 g of hydrofluoric
acid, what V of gas
will be produced @ 28.3°C
and 780 torr?

when 24.6 g of sodium
carbonate Reacts w/
5.63 g of hydrofluoric
acid, what V of gas
will be produced @ 28.3°C
and 780 torr?

$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$

$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$

24.6 g Na_2CO_3

5.63 g HF

$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$

$24.6\ g\ Na_2CO_3 \times \frac{1\ mol\ Na_2CO_3}{106\ g\ Na_2CO_3} = 0.232\ mol\ Na_2CO_3$ have

$5.63\ g\ HF \times \frac{1\ mol\ HF}{20.0\ g\ HF} = 0.282\ mol\ HF$ have

$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$

$24.6\ g\ Na_2CO_3 \times \frac{1\ mol\ Na_2CO_3}{106\ g\ Na_2CO_3} = 0.232\ mol\ Na_2CO_3$ have

$5.63\ g\ HF \times \frac{1\ mol\ HF}{20.0\ g\ HF} = 0.282\ mol\ HF$ have $\times \frac{1\ mol\ Na_2CO_3}{2\ mol\ HF} = 0.141\ mol\ Na_2CO_3$ Need

$$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$$

$$24.6\ g\ Na_2CO_3 \times \frac{1\ mol\ Na_2CO_3}{106\ g\ Na_2CO_3} = \boxed{0.232\ mol\ Na_2CO_3 \text{ have ER}}$$

$$5.63\ g\ HF \times \frac{1\ mol\ HF}{20.0\ g\ HF} = \boxed{0.282\ mol\ HF \text{ have LR}} \times \frac{1\ mol\ Na_2CO_3}{2\ mol\ HF} = \boxed{0.141\ mol\ Na_2CO_3 \text{ Need}}$$

$$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$$

$$5.63\ g\ HF \times \frac{1\ mol\ HF}{20.0\ g\ HF} = 0.282\ mol\ HF \times \frac{1\ mol\ CO_2}{2\ mol\ HF} = 0.141\ mol\ CO_2$$

0.282 mol HF — have LR

$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$

$P = 780.\text{ torr} \times \frac{1\text{ atm}}{760\text{ torr}} = 1.03\text{ atm}$

$V = ?$

$n = 0.141\text{ mol}$

$T = 28.3°C + 273 = 301.3\text{ K}$

$5.63\text{ g HF} \times \frac{1\text{ mol HF}}{20.0\text{ g HF}} = 0.282\text{ mol HF}$ (new LR) $\times \frac{1\text{ mol } CO_2}{2\text{ mol HF}} = 0.141\text{ mol } CO_2$

$$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$$

$P = 780.\text{torr} \times \frac{1\,\text{atm}}{760\,\text{torr}} = 1.03\,\text{atm}$

$V = ?$

$n = 0.141\,\text{mol}$

$T = 28.3\,^\circ C + 273 = 301.3\,K$

$$V = \frac{nRT}{P} = \frac{(0.141\,\text{mol})(0.0821\,\frac{L\cdot atm}{mol\cdot K})(301.3\,K)}{1.03\,atm}$$

$$5.63\,g\,HF \times \frac{1\,mol\,HF}{20.0\,g\,HF} = 0.282\,mol\,HF \times \frac{1\,mol\,CO_2}{2\,mol\,HF} = 0.141\,mol\,CO_2$$

(0.282 mol HF: have, LR)

$$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$$

$P = 780.\text{torr} \times \frac{1\,\text{atm}}{760\,\text{torr}} = 1.03\,\text{atm}$

$V = ?$

$n = 0.141\,\text{mol}$

$T = 28.3^\circ C + 273 = 301.3\,K$

$$V = \frac{nRT}{P} = \frac{(0.141\,\text{mol})(0.0821\,\frac{L\cdot atm}{mol\cdot K})(301.3\,K)}{1.03\,\text{atm}} = 3.39\,L\ CO_2$$

$$5.63\,g\,HF \times \frac{1\,mol\,HF}{20.0\,g\,HF} = 0.282\,mol\,HF \times \frac{1\,mol\,CO_2}{2\,mol\,HF} = 0.141\,mol\,CO_2$$

(0.282 mol HF: have LR)